PREPARING PROSPECTIVE MATHEMATICS TEACHERS TO DESIGN AND TEACH TECHNOLOGY-BASED LESSONS

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This study is an ongoing research aiming to develop four prospective secondary mathematics teachers' skills in designing and teaching technology-based lesson plans within the scope of 14-week Teaching Practice course. The Dynamic Geometry Task Analysis and Instrumental Orchestration frameworks have been chosen as the conceptual basis of the study. In this study, qualitative research paradigm has been adopted and action research methodology aiming to plan a cyclical process of designing technology-based lesson plans through modifying, implementing and reflecting has been used. Data mainly consisted of individual/group interviews, lesson observations/field notes and multiple versions of lesson plans. Data analysis process is in progress, however, preliminary results focusing on one task of one participant indicated that the participant developed, evaluated and implemented her technology-based task in the light of adopted frameworks.

Keywords: mathematical task design, technology-based lesson plan, instrumental orchestration, prospective mathematics teachers, classroom practices.

INTRODUCTION

In many countries, using digital technologies has been considered as an effective way to improve teaching and learning in mathematics, which in the last few decades has given a direction to the research on the integration of technology into pedagogical practice. However, research show that the incorporation of technology into mathematics education in ordinary classrooms has been slow and that teachers' failure to change their practices with the use of digital technologies contrary to their optimism that technology would support a greater focus on conceptual understanding (Drijvers et al. 2013; Laborde, 2001; Monaghan, 2004). In other words, it has been indicated that digital technologies have not still been utilised as a means of transforming mathematics in ordinary classrooms as proposed and studied by the researchers in the field. Therefore, it is important for teachers to develop mathematical tasks that incorporate digital technologies in a more high-level cognitive demand as described by Smith and Stein (1998). Furthermore, other studies (Lagrange & Ozdemir Erdogan, 2009; Ruthven, 2009) have pointed out that teachers' plans might sometimes be overly optimistic regarding the potentials of technological tools. There is the additional chance that they might encounter unforeseen problems once in the classroom. These are issues that are particularly crucial in teacher education and need to be taken into consideration when working with prospective teachers. In line with this idea, the main objective of this study is to focus on and develop the skills of prospective teachers as future teachers of today in designing and teaching technology-based lesson plans in secondary mathematics education context.

Along this direction, two research questions guide this study: "How do prospective secondary mathematics teachers develop technology-based lesson plans?" and "How do they reflect these lesson plans into their teaching in ordinary classrooms?"

CONCEPTUAL FRAMEWORK

Two frameworks are used to reveal prospective teachers' skills in preparing and teaching technology-based lessons. By using the Dynamic Geometry Task Analysis framework (Trocki & Hollebrands, 2018), we aim to examine and improve the content of technology-based mathematical tasks particularly focusing on mathematical depth and technological action. In addition, by using Instrumental Orchestration framework (Drijvers et al., 2010; Trouche, 2004), we aim to illuminate prospective teachers' classroom practices with the use of digital technologies. The detail information regarding the frameworks is given in the following part.

The Dynamic Geometry Task Analysis Framework

For the aims of this study, in order to conceptualise the task design of prospective teachers, we utilise The Dynamic Geometry Task Analysis framework (see Table 1), which is recently developed by Trocki and Hollebrands (2018). By considering the research-based recommendations for using dynamic software in mathematics teaching and learning, Trocki and Hollebrands call our attention to two components: mathematical depth and technological action. They based the first component, mathematical depth, mainly on Smith and Stein's (1998) mathematical task analysis guide through assimilating the characteristics of lower level (memorisation, procedures without connections) and higher-level tasks (procedures with connections, doing mathematics) for the tasks designed in a dynamic geometry environment. For example, while Smith and Stein (1998) described doing mathematics as "require students to explore and understand the nature of mathematical relationships", Trocki and Hollebrands (2018) associate this for mathematical depth of Level 4 code. The component of technological action was also developed by considering the studies related to the use and importance of dynamic software in mathematics education (Arzarello, Olivero, Paola, & Robutti, 2002; Baccaglini-Frank & Mariotti 2010; Christou et al., 2004; Hollebrands 2007; Hölzl, 2001; Sinclair, 2003). For instance, Sinclair's (2003) research related to promoting students' exploration with pre-constructed dynamic geometry sketches shaped the technological affordance G in Trocki and Hollebrands' (2018) framework.

Table 1: The Dynamic Geometry Task Analysis Framework

Allowance for Mathematical Depth	
Levels	**Hierarchical Levels and Descriptions**
N/A	Prompt requires a technology task with no focus on mathematics.
0	Sketch does not have mathematical fidelity required to respond to prompt.
1	Prompt requires student to recall a math fact, rule, formula, or definition.
2	Prompt requires student to report information from the construction. The student is not expected to provide an explanation.
3	Prompt requires student to consider the mathematical concepts, processes, or relationships in the current sketch.
4	Prompt requires student to explain the mathematical concepts, processes, or relationships in the current sketch.
5	Prompt requires student to go beyond the current construction and generalise mathematical concepts, processes, or relationships.
Types of Technological Action	
N/A	Prompt requires no drawing, construction, measurement, or manipulation of current sketch.

A	Prompt requires drawing within current sketch.
B	Prompt requires measurement within current sketch.
C	Prompt requires construction within current sketch.
D	Prompt requires dragging or use of other dynamic aspects of the sketch.
E	Prompt requires creation/consideration of multiple examples from which one can generalise.
F	Prompt requires a manipulation of the sketch that allows for recognition of emergent invariant relationship(s) or pattern(s) among or within geometrical object(s).
G	Prompt requires manipulation of the sketch that may surprise one exploring the relationships represented or cause one to refine thinking based on themes within the surprise (adapted from Sinclair (2003), p. 312).

By conceptualising hierarchical levels of mathematical depth of a task and technological action used for such mathematical depth, we aim to examine how prospective mathematics teachers' task design evolve focusing on these components and to provide the tools of language to guide them in technology-based task design.

Instrumental Orchestration

After designing the technology-based tasks for a lesson plan, prospective mathematics teachers implemented these plans in their school placements. The instrumental orchestration framework (Drijvers et al. 2010; Trouche, 2004) is used to describe observed teaching practices aiming to conceptualise the structures of their designed activities. Instrumental Orchestration points out the necessity for teachers to guide their students' instrumental genesis by systematic organisation of their tasks and use of the various artefacts available. Guin and Trouche (2002) define instrumental orchestration underlining four components: "a set of individuals; a set of objectives (related to the achievement of a type of task or the arrangement of a work- environment); a didactic configuration (that is to say a general structure for the plan of action); a set of exploitations of this configuration" (p. 208).

Research on Instrumental Orchestration (e.g. Drijvers et al., 2010; Drijvers, 2012; Trouche, 2004) has provided operational descriptions, based on a combination of data-driven and theory-driven analysis, for several orchestration types relating to particular didactical configurations and exploitation modes (i.e. Technical-demo, Explain-the-screen, Discuss-the-screen, Spot-and-show, Sherpa-at-work). In this study, while preparing the lesson plans, prospective teachers were encouraged to consider the possible orchestration types relating to particular didactical configurations and exploitation modes in which they could achieve their planned objectives. These parts of instrumental orchestration are related to decisions, which teachers make before teaching in advance. However, Drijvers et al. (2010) introduced an additional third component, a didactical performance, in order to emphasise teachers' ad hoc strategies when unexpected aspect of the mathematical task or the technological tool occurs in classroom teaching with regard to chosen didactic configuration and exploitation mode. Hence, during school placements of prospective teachers, we focused on the parts that may emerge spontaneously during a lesson and the strategies they developed when unexpected issues occured in the classroom as a result of applying techniques instrumented by the available technological tools.

By focusing on already defined orchestration types in the literature (Drijvers et al. 2010; Drijvers, 2012), we aimed to picture what type of orchestrations occured in prospective teachers' classroom practices, particularly how they structured their technological actions for supporting pupils' mathematical depth by using their designed tasks.

RESEARCH METHODOLOGY

The aim of this study is to plan a process, where prospective mathematics teachers design and teach technology-based lessons in actual classroom environments followed by reflection on the planning and teaching experiences. In this sense, we studied actions that prospective mathematics teachers took to develop and improve their skills in planning and teaching technology-based lessons through the collaborative work with researchers. This was done through multiple cycles of action, data collection and analysis, and reflection. Hence, an action research methodology, one of the qualitative research methods, was adopted in the study as the enquiry at stake was to understand, evaluate, change and improve educational practice (Bassey, 1998). By using an action research, one aims to generate new knowledge by pursuing action and learning through action leading to personal or professional development through a cyclical process consisting of planning, acting, observing and reflecting (Koshy, 2005; O'Leary, 2004). In other words, researchers initially plan about what they want to change, then they act and observe the process and consequences of the change. In the following step, they reflect on the process and consequences, accordingly they re-planned the process (Kemmis & McTaggart, 2000).

Participants

Participants of the study were four prospective secondary mathematics teachers, who were enrolled in a secondary mathematics education program at a state university in Turkey. The participants were in their final year of the program during which they experienced classroom teaching in schools as a requirement for the 'Teaching Practice' course. The participants of the study were chosen based on the criterion sampling method (Patton, 2002). Their prior knowledge regarding the use of technological tools used in mathematics education was considered as a criterion. The chosen prospective teachers took almost all of the theoretical mathematics and mathematics education courses in their teacher training program, particularly, related to the use of technology in mathematics education such as Mathematics Software and Using Information Technologies in Mathematics Education courses. In addition, they had the opportunity to observe the real classroom environments for an academic semester while taking the School Experience course.

Research Plan

After identifying the focus of the study, an initial research plan including three cycles (see Figure 1) was developed by the researchers (the authors of this paper) within the scope of the 14-week Teaching Practice course. The initial research plan was revised based on participants' responses and actions throughout the process.

The first cycle was designed to educate prospective mathematics teachers regarding designing technology-based tasks and lesson plans in the light of two frameworks of the study. Based on this, prospective teachers developed lesson plans on the topic they chose. At the end of this cycle, the developed lesson plans were examined by the researchers and then each of prospective teachers was given individual feedback. The second cycle consisted of micro-teaching process, in which each prospective teacher taught their lessons hypothetically to fellow teachers and the researchers. In the following step, the whole group initially discussed each prospective teacher's micro-teaching process considering the classroom context and teaching with technology.

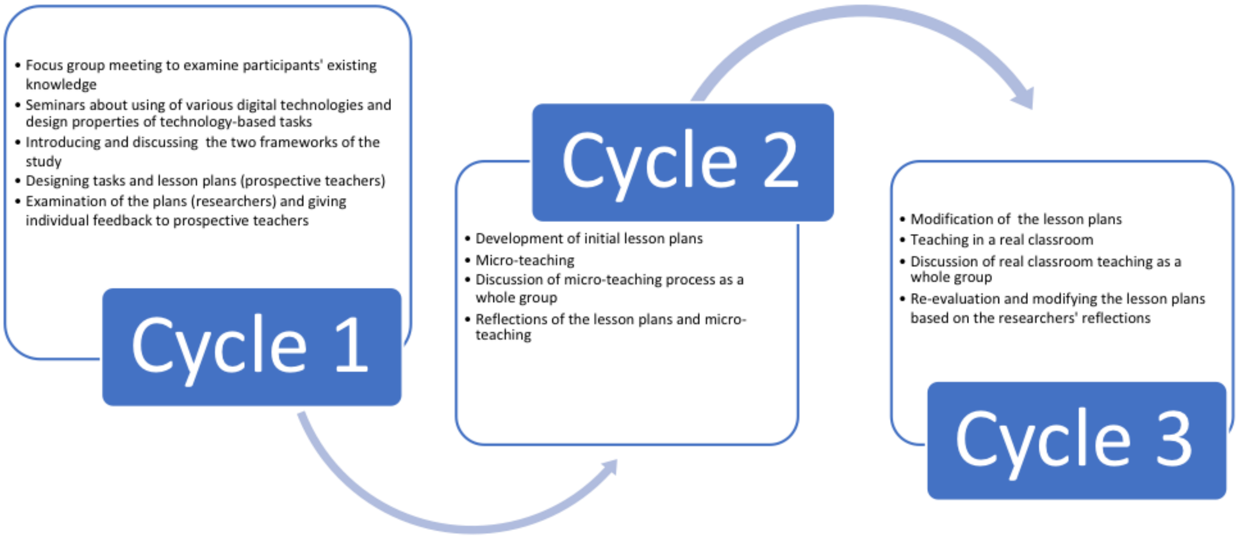


Figure 1: The three cycles of the research plan

Then, the revised lesson plans and video records of micro teaching were examined by the researchers and then each of them was given individual feedback. During the last cycle, as a first step, prospective teachers finalised the lesson plans based on their micro-teaching experiences and feedback given by the researchers and fellow participants. Then, prospective teachers implemented their revised lesson plans in real classrooms. Finally, they re-evaluated and modified lesson plans based on the classroom implementation experiences and feedback by the researchers as well as by the post-lesson discussion conducted with the whole group.

Data Collection

Within the scope of the action research, multiple data sources were collected to increase the validity of the research. In addition, the written and visual materials, which are important in analysing the findings, were included in the research (Flick, 2018). The data collection process, the period to be collected, and the goals of collecting the particular data source are detailed in the table below (see Table 2).

Table 2. The data collection process of the study

Data	The Period	Goal
The First Focus Group Meeting	First week of the research	to identify participants' thoughts, perceptions and existing knowledge regarding the use of technology in mathematics education.
Lesson Plans	-After training program (Week 6) -After feedback given based on first design process (Week 8) -After implementation in real classroom and Focus Group (Week 14)	to examine how prospective teachers develop/change/evolve technology-based lesson plans.

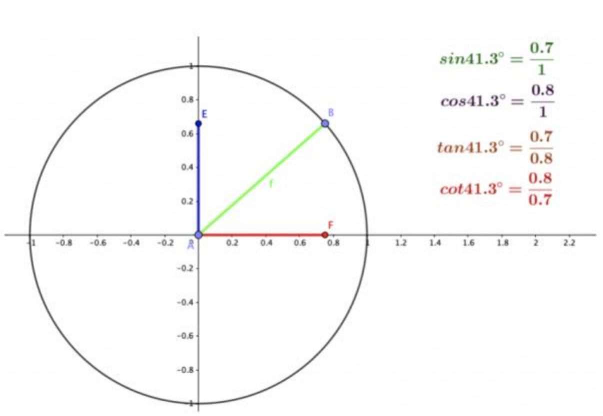
Microteaching Video Records	The participants taught their lesson plans to the fellow participants and the researchers before implementing them in real classrooms (Week 8).	to evaluate the participants' micro-teaching of their lesson plans and provide feedback on their micro-teaching.
Real Classroom Video Records	The participants implemented their developed lesson plans in real classrooms (Week 10-12).	to examine participants' implementations of the developed lesson plans in school placements.
Observation Notes	While participants implemented the lesson plans in real classrooms, researchers took observation notes (Week 10-12).	to examine participants' implementations of the developed lesson plans in school placements.
Video Records of Focus Group Interview	After all participants implemented the developed lesson plans, a focus group discussion took place (Week 13).	to examine each participant's classroom practices in a group discussion with the researchers and all the participants.

Data Analysis

All three cycles of the research were completed; however, data analysis is in progress and still ongoing. Therefore, the analysis process of only one participant of one technology-based task has been shared in this section. The designed technology-based task has been analysed according to Task Analysis framework considering the hierarchical levels of mathematical depth of the task and technological action used for such mathematical depth. The prospective teacher's own accounts during individual interviews about what mathematical depth she aimed in this task and what kind of technological action she aimed to use in order to achieve her intended depth has been identified. To characterise how this prospective teacher practiced this task in the classroom, we made use of the already identified orchestration types in the literature (Drijvers et al., 2010). In particular, a set of descriptors for teacher-led whole class teaching has been used as codes in order to analyse the structural interaction in teacher's classroom practices. Therefore, video records of the task implementations and the prospective teacher's instructions in micro teaching as well as in real classroom environment have been evaluated combining together with observer field notes and post-lesson interviews. Additionally, looking at the different cycles and multiple stages of her development in the process, changes in the designed task in terms of mathematical depth, technological action used and orchestration types chosen have been examined in detail. The triangulation aimed to be used in order to ensure the validity of data. Specifically, the plan of the designed task, the video records of the implementation of this task, observation notes, and the video records of focus group interviews allowed us to validate and verify the data.

PRELIMINARY RESULTS

As mentioned above, in this section, we share the preliminary results of one technology-based task designed by one participant. Particularly, we examine and describe the mathematical depth and the technological action of her designed task as well as the instrumental orchestrations while teaching this task in the classroom. Her chosen topic was Trigonometry and this specific task consisted of Unit Circle investigation with the use of GeoGebra. For the task, she prepared a dynamic GeoGebra file and developed 10 sequential prompts (see Figure 2) involving steps for students to explore trigonometric ratios. By designing those questions, she aimed to show how the lengths of the ratios change according to the angle, and how changes in angle affect measures of side length, and also wanted her students to discover while x axes represent the cosine, y axes represent the sine through dragging the movable point around the unit circle.



1. Observe the changes by dragging point B. What is your conjecture about variants and invariants?
2. Measure the lengths of three-line segments by using the measurement tool. Observe the screen by dragging point B, again. Is your conjecture from #1 is true?
3. Discuss why |AB| does not change while |EA| and |AF| are changing. Explain the relationship of it with the unit circle.
4. What could be said about the m(BAF) based on the dragging of point B. What is your conjecture about it?
5. Measure the angle BAF. Is your conjecture from #4 is true?
6. Drag the point B until the measure of angle BAF is 30 degrees. We have already learnt to find a value of sine. Could we find the equality of sine 30 = ½ on the figure?
7. Calculate the length of line segment |BF| by selecting the points B and F using the line segment tool bar. Is there any relationship between |BF| and |EA|? Explain.
8. Consider the #6 again, can we find the sine 30 on the unit circle? Explain.
9. Can we find the values of tan30 and cot45 based on the inferences obtained from #8? Why?
10. Can you find the value of tan55 based on the discussion so far?

Figure 2. A screenshot from the GeoGebra file and 10 sequential questions guiding the task

At the end of the first cycle during the individual interviews with the researchers, she realised that the task would not reach the generalisation level that she aimed in terms of mathematical depth because of missing steps for students to reach generalisation. Hence, she revised and changed some questions in the sequence of the task. After micro teaching the designed activity, she stated that the main thing that she thought about was the meaning and importance of the instrumental orchestration framework in classroom teaching since she failed to manage her activity as she imagined and planned to practice. In this sense, micro teaching cycle of the process was of critical importance in enabling her to reconsider and improve the instrumental orchestrations of her task, specifically discuss-the-screen, link-screen-board and predict-and-test. In the last cycle, starting to implement of her plan in a real classroom also led her to change and improve the instrumental orchestrations used in this specific task. Additionally, she noticed that she could use a slider and animate it for the point around the unit circle instead of dragging it by hand, which affected her management of the classroom discussion and also helped her to achieve the aimed mathematical depth better. Particularly, adding a slider eliminated angle measuring related issues experienced during micro teaching and also prevented the limited dragging. The preliminary results show that she developed, evaluated and implemented her technology-based task in the light of adopted frameworks. The next step in the analysis process is to develop a more general model by comparing and contrasting parts of changes, evolution and/or development of four prospective teachers' technology-based lesson plans.

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